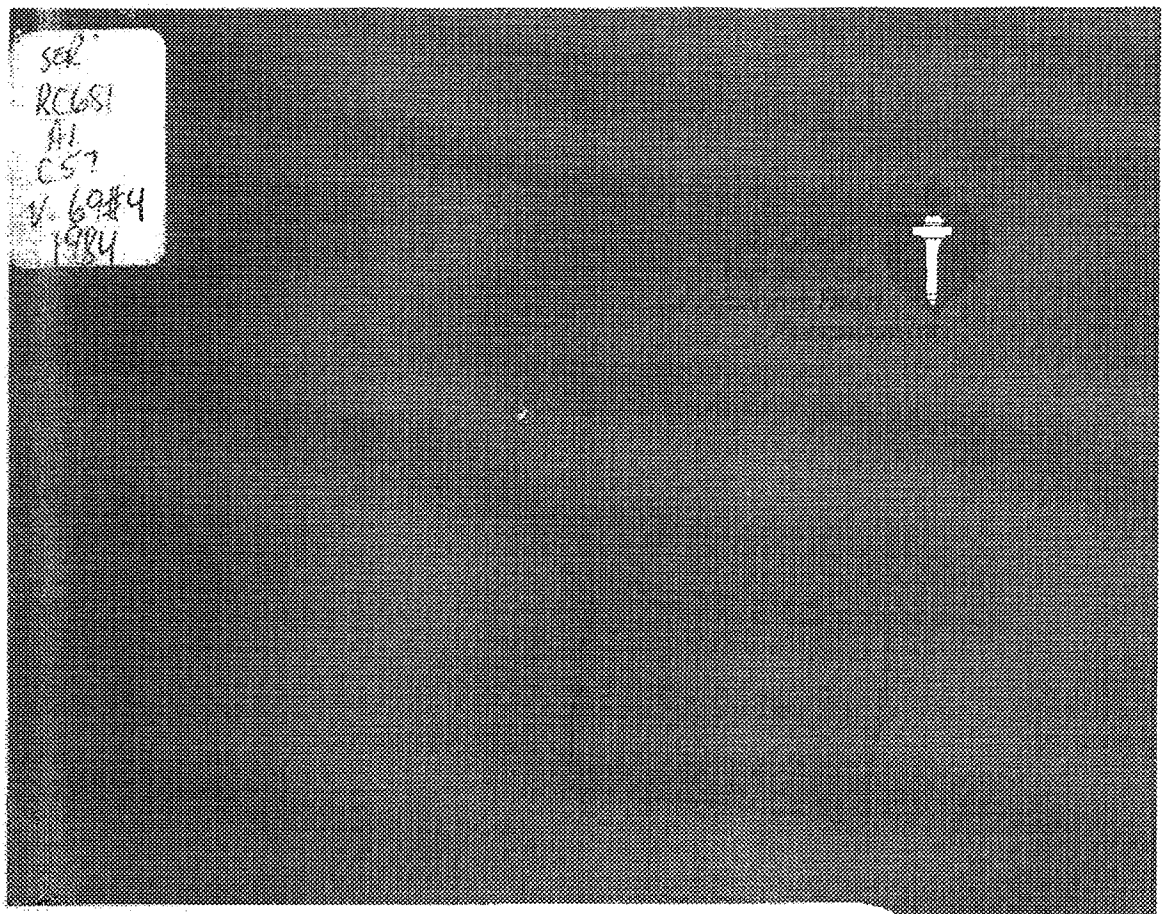

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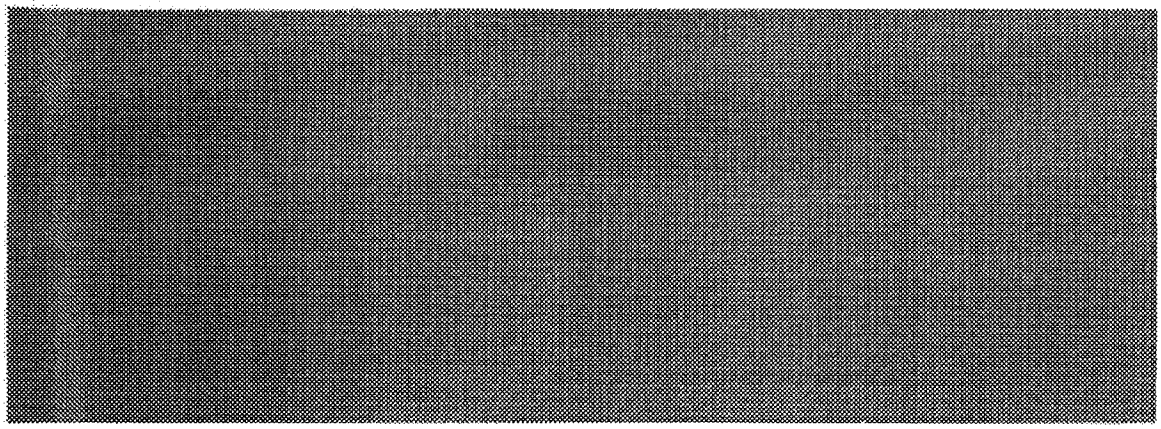

Coumadin and aspirin in prevention of recurrence after transluminal coronary angioplasty: a randomized study

MARGARET A. THORNTON, M.D., ANDREAS R. GRUENTZIG, M.D., JAY HOLLMAN, M.D., SPENCER B. KING, III, M.D., AND JOHN S. DOUGLAS, M.D.

ABSTRACT To determine the influence of adjunctive treatment with coumadin or aspirin on recurrence rate after percutaneous transluminal coronary angioplasty (PTCA), 248 patients in whom PTCA was assessed to be a primary success were randomized to either 325 mm aspirin daily or to coumadin treatment sufficient to maintain a prothrombin time 2 to 2.5 times the control value. The follow-up protocol included stress testing and coronary angiographic examinations 3 to 6 months after PTCA. All patients were followed for at least 9 months. Of the 122 patients randomized to coumadin 44 (36%) had recurrent stenoses as opposed to 34/126 (27%) of patients on aspirin, a difference that did not reach statistical significance at the .05 level. However, patients with at least a 6 month history of angina demonstrated a significantly different response to adjunctive treatment in that 19/43 (44%) of coumadin patients as compared with 10/48 (21%) of aspirin patients had recurrent stenoses ($p < .05$). Thus, coumadin was not shown to be more effective than aspirin as adjunctive treatment after PTCA, while aspirin was shown to be superior to coumadin in patients with a longer history of angina.
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AFTER REVASCULARIZATION PROCEDURES such as coronary artery bypass grafting and coronary angioplasty there is often recurrence of stenosis. Several adjunctive therapies have been recommended to prevent thrombus formation with closure of graft or vessel. Early investigators in angioplasty recommended the use of coumadin as long-term adjunctive therapy after femoropopliteal transluminal angioplasty with the Dotter technique.[1] Thereafter, coumadin therapy was also used for peripheral dilatation with the balloon technique[2] and later applied in coronary angioplasty.[3, 4] Long-term patency of 75% was achieved in European patients with adjunctive coumadin therapy after percutaneous transluminal coronary angioplasty (PTCA). The use of coumadin therapy was also supported by selected studies of the effectiveness of anticoagulants in patients after myocardial infarction.[5, 6] Other studies demonstrated benefit from the administration of aspirin after infarction.[7–9] Schneider et al.[10] reported the results of a randomized study comparing aspirin and coumadin therapy in patients undergoing femoral endarterectomy or femoropopliteal bypass grafting. They concluded that patients undergoing endarterectomy benefited from aspirin therapy, whereas in patients with bypass grafts, coumadin was preferable. Later it became apparent that centers at which coumadin was not used had similar results with respect to long-term patency after PTCA,[11, 12] as did centers at which this adjunctive therapy was used. In the face of this controversy, our study was undertaken to evaluate the effectiveness of these two adjunctive therapies in preventing recurrent stenosis after coronary dilatation by means of a randomization process and in cooperation with referring physicians.

Methods

Patients. Between December 15, 1980 and September 15, 1981, 299 patients underwent PTCA, 248 of the procedures were primary successes and the patients could be randomly assigned to receive aspirin or coumadin therapy for 6 months after dilatation. Angioplasty was performed via the femoral route by techniques described elsewhere.[13] All patients were followed for at least 9 months after PTCA.

Criteria for inclusion in study. A procedure was considered a primary success if the stenosis could be passed by the dilatation catheter, resulting in an improvement in the stenosis. This improvement was measured by a decrease in the percent diameter of the stenosis of at least 20% as a result of the dilatation procedure.[14] Patients in whom the stenosis could not be passed

From the Department of Medicine and Radiology, Emory University School of Medicine and Emory University Hospital, Atlanta.
Address for correspondence: Andreas R. Gruentzig, M.D., Emory University Hospital, 1364 Clifton Rd., Atlanta, GA 30322.
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or whose arteries reoccluded within 48 hr of the procedure necessitating either emergency bypass surgery or elective surgery at a later date were excluded from the study. Patients with myocardial infarction documented by Q wave criteria during the hospital stay were also excluded. Other exclusion factors were a history of gastrointestinal bleeding, cerebrovascular accident, or other contraindications to anticoagulant therapy.

Study and design. The two groups resulting from the randomization process were placed on adjunctive therapy in the hospital after successful PTCA. The first group comprised 126 patients who received 650 mg aspirin the day before PTCA and were placed on one tablet (325 mg) aspirin per day thereafter for 6 months. The second group, which consisted of 122 patients, received 650 mg aspirin the day before angioplasty in the same fashion, and also were given 325 mg aspirin daily until discharge. In addition, this group was placed on coumadin therapy immediately after PTCA and their prothrombin time values had generally reached 2 to 2.5 times control values at the time of discharge. Adjunctive medical therapy was monitored by referring physicians after the patients' discharge. The use of additional therapy, such as β-blocking agents or nitrates, was left to the discretion of the referring centers. Nifedipine was not available at this time on the United States market. If not contraindicated clinically, all patients underwent Bruce protocol stress tests or thallium first-pass exercise tests immediately before angioplasty and 2 days after the procedure.

The study was designed for a sample size of 348 patients in each group, with a power of .80 and a p value of .05. In September 1981, an initial analysis of the data was performed. At this point, 121 patients had been followed up for a period of 4 months and a substantially higher recurrence rate was observed in those patients who had been placed on coumadin therapy. A clinical decision was made to complete the study with only the 248 patients that had entered at that point.

Follow-up protocol. Referring physicians were requested to administer stress tests to each patient at 3-month intervals after PTCA and to obtain control angiograms 6 to 9 months after the procedure. Patients were also informed of this protocol. Letters were sent to physicians and patients 3 and 6 months after the procedure as reminders. Referring physicians were requested to forward copies of reports of stress tests and angiograms to us for analysis. Telephone calls were made to referring physicians 1 to 2 months after mailing of the reminders if no response had yet been received. Repeat mailings resulted in further information.

Recurrence. Recurrence was defined as the loss of at least 50% of the gain in luminal diameter accomplished by dilatation. Stenoses were measured in at least three oblique projections and a mean was calculated with a computerized caliper.* Meier et al.[15] have shown this method to be more reliable than the use of single projections alone. Follow-up angiograms were forwarded to us for analysis and "gain" was assessed. For example, an 80% stenosis on initial study may be reduced to a 20% diameter narrowing as a result of dilatation; this represents a 60% gain. If on a control angiogram a patient was found to have greater than a 50% stenosis representing a loss of more than half of the initial gain, he was considered to be a recurrence even in the absence of clinical symptoms. In the absence of angiographic documentation, a reversion to a positive stress test result by clinical or electrocardiographic criteria in a patient with a positive exercise test before PTCA and a negative test after the procedure was also considered to indicate a recurrence.

Duration of anginal symptoms. Duration of angina before PTCA was assessed from data supplied by referring physicians, if available. Otherwise, this information was obtained through patient interviews by hospital staff physicians.

Compliance with medication. Questionnaires designed to assess the degree of patient compliance with medication were sent to referring physicians. These data were reported in the form of a subjective assessment by the physician of the degree of compliance by the patient, which was described as excellent, good, fair, poor, or no compliance. In addition, prothrombin time values were requested from those patients maintained on coumadin and were reported as a comparison with control plasma values. Results reported as percent prothrombin activity were also accepted. For purposes of analysis, adequate coagulation was defined as $\geq$1.9 times the control prothrombin time value or $\leq$20% prothrombin activity.

Statistics. The data were analyzed by means of a χ^2 analysis or by an unpaired Student *t* test in the case of comparison of means. Probabilities were taken from standard distribution tables and considered statistically significant at the .05 level. A discriminate analysis was performed on the data along with cross-table analysis to determine the predictive potential of selected variables on the outcome.

Results

Data from the 248 patients who were placed on adjunctive therapy were analyzed by the principle of intention to treat. The two groups that resulted from the randomization process were comparable with respect to epidemiologic factors such as age, sex, and the vessel that was dilated. The extent of disease as well as the response to dilatation as measured by pressure gradients and percent diameter of stenosis before and after dilatation were also similar (table 1).

Follow-up data. Objective follow-up information was obtained in 92% (228/248) of all patients, and the amount of follow up information obtained for the two subgroups did not differ significantly. Of the patients

TABLE 1
Characteristics of patients and procedures

	Coumadin	Aspirin
n	122	126
Age (yr)	53	53
	(range 33–72)	(range 31–77)
Men (%)	81	79
Vessel dilated (%)		
LAD	69	75
RCA	22	20
LCx	3	2
LM	0	1
SVG	6	2
Pressure gradient (mm Hg)[a]		
Before PTCA	46.7 ± 17.0	47.9 ± 16.1
After PTCA	15.0 ± 9.3	14.6 ± 8.1
Diameter stenosis (%)[a]		
Before PTCA	72.7 ± 13.8	68.8 ± 14.8
After PTCA	28.9 ± 13.1	27.2 ± 12.4

LAD = left anterior descending coronary artery; RCA = right coronary artery; LCx = left circumflex coronary artery; LM = left main coronary artery; SVG = saphenous vein graft.
[a]Mean ± SD.

*A2D Prodical 1101 Programmable Digital caliper.

on coumadin therapy 95% (116/122) had either an exercise test or a coronary angiogram as compared with 89% (112/126) of aspirin patients (χ^2 = .01, NS). Control angiograms were obtained in 77% (94/122) of coumadin patients as opposed to 67% (84/126) of patients on aspirin (χ^2 = 3.30, NS). Patients were followed for a minimum of 9 months (range 9 to 18).

The higher percentage of control angiograms obtained for the coumadin group was related to a higher recurrence rate in that group. When those patients with recurrences documented by angiography were eliminated, the number of patients with negative control angiograms in the coumadin and aspirin subgroups was similar. It should be noted that in only one case was it necessary to define recurrence on the basis of the results of an exercise stress test alone without coronary angiography.

Recurrence rate. The recurrence rate in the sample as a whole after 9 months of follow-up was 31.0% (78/248). Of these patients, 51/78 (65%) were available for a second dilatation procedure, with 45/51 (88%) having a favorable outcome. Detailed analysis of data from patients undergoing a second dilatation is not relevant to this study and therefore will not be further discussed. The coumadin subgroup had a recurrence rate after 9 months of 36.1% (44/122) as compared with a 27.0% (34/126) rate in the group on aspirin therapy (χ^2 = 2.37, NS).

Duration of anginal symptoms. The mean duration of angina before PTCA was 6.94 ± 9.78 months in patients on coumadin therapy as opposed to 7.73 ± 11.77 months in patients on aspirin (mean ± SD). Spurious results in five patients who did not exclusively belong to either therapy group and who had a longer than 72 month history of angina were eliminated from the analysis.

In the entire sample of 248 patients, the duration of anginal symptoms in the months before PTCA made no significant difference in the determination of recurrence rate. On more detailed analysis, when duration of angina categories were broken down by therapy group, in all subgroups in which members had at least a 3 month history of angina the recurrence rate indicated that aspirin therapy was superior. In the subgroup with a 3 to 5 month history of angina this result reached statistical significance at the .05 level (table 2).

When patients with a history of angina of 6 or more months were considered separately, the difference in recurrence rates between patients on coumadin and those on aspirin was statistically significant. The subgroup of coumadin patients with a longer duration of angina had a 44% recurrence rate (19/43) as opposed to a 21% rate (10/48) in patients on aspirin with a similar history (χ^2 = 5.70, $p < .05$). In patients with less than a 6 month history of symptoms the difference in recurrence rate between coumadin and aspirin subgroups was not statistically significant, with 32% (25/79) of coumadin patients and 31% (24/78) of aspirin patients having recurrent stenosis.

Compliance. Compliance data were provided for 85% (210/248) of patients in the study. The number of respondents with excellent or good compliance was greater in the aspirin than in the coumadin group as a whole, but the difference was not significant. A significant difference between the two groups was identified in that the percentage of coumadin patients on no therapy was higher than the percentage on no therapy in the aspirin group. Twenty-six percent (28/108) of patients on coumadin supplying information were not compliant with therapy as opposed to 15% (15/102) of aspirin patients ($p < .05$). However, the recurrence rate in these subgroups was not statistically significantly different (table 3). Prothrombin time values were received for 63% (77/122) of patients on coumadin, of which 35% (27/77) were assessed as adequate. Twelve of these 27 patients (44%) had a recurrence.

Further analysis of compliance data revealed that when subgroups divided by degree of compliance with therapy were analyzed separately, no subgroup randomized to coumadin was found to have a recurrence

TABLE 2
Duration of anginal symptoms

	History of angina (mo)									
	< 3		3–5		6–11		12–23		≥24	
Recurrence	34/100		15/57		12/37		10/23		7/31	
					χ^2 = 3.74, NS (4 df)					
Therapy	C	A	C	A	C	A	C	A	C	A
Recurrence	13/46	21/54	12/33	3/24	9/20	3/17	7/11	3/12	3/12	4/19
	NS		χ^2 = 4.08, $p < .05$		χ^2 = 3.14, $p < .1$		χ^2 = 3.49, $p < 1$		NS	

C = coumadin; A = aspirin.

TABLE 3
Compliance with adjunctive therapy

	Coumadin		Aspirin	
	n	%	n	%
Supplied data	108/122	89	102/126	81
Excellent/good	75/108	69	80/102	78 (NS)
Fair/poor	5/108	5	7/102	7
No compliance	28/108	26	15/102	15 ($p < .05$)
RR in no compliance group	9/28	32	3/15	20 (NS)

RR = recurrence rate.

rate less than 30%. In contrast, within the aspirin group the only subgroup with over 30% recurrences was composed of those patients who failed to supply compliance information. This result reinforces the finding of a higher recurrence rate in the group of patients, as a whole, who were placed on coumadin therapy. It should be noted that among patients in whom compliance was good or excellent, recurrence rates were 31% in the coumadin group and 29% in the aspirin group. This finding again fails to demonstrate an advantage of coumadin over aspirin therapy even under the most optimal conditions (figure 1).

Analysis of data from patients with a longer history of angina. At this point in the analysis of data two statistically significant differences had been identified. The first of these requires a separate consideration of patients with a minimum of 6 months of anginal symptoms before PTCA and demonstrated a significant difference in recurrence rate between patients maintained on coumadin as opposed to those on aspirin.

The second significant finding was that a higher percentage of the physicians of patients randomized to coumadin as opposed to aspirin therapy reported no patient compliance with adjunctive therapy. It then became necessary to resolve the question of whether the difference in recurrence rate between patients on coumadin and those on aspirin with a longer history of angina was due to the larger percentage of coumadin patients who did not comply with therapy. We analyzed recurrence, availability of compliance information, and degree of compliance with medication in the sample as a whole and in the subgroups based on duration of angina. In considering the compliance data for patients with a minimum of a 6 month history of angina, we found no significant difference in the degree of compliance with therapy between patients randomized to coumadin and those on aspirin. Twenty-four percent (8/34) of coumadin patients in this subgroup reported no compliance with therapy as opposed to 14% (6/42) of aspirin patients ($\chi^2 = 1.07$, NS). The patients with a longer history of angina on coumadin therapy were also comparable as a subgroup to the entire group of patients randomized to coumadin with regard to the degree of therapy. (In the entire sample, 26% [28/108] of coumadin patients reported no compliance with therapy.) Furthermore, in a more detailed analysis of the patients who reported at least a 6 month history of angina, the recurrence rate was recalculated after eliminating those patients for whom no compliance with medication was reported. The difference in recurrence rate was again present, although it was not statistically significant. Of patients on coumadin reporting some compliance with therapy, 42% (11/26) had recurrent stenoses as compared with 22%

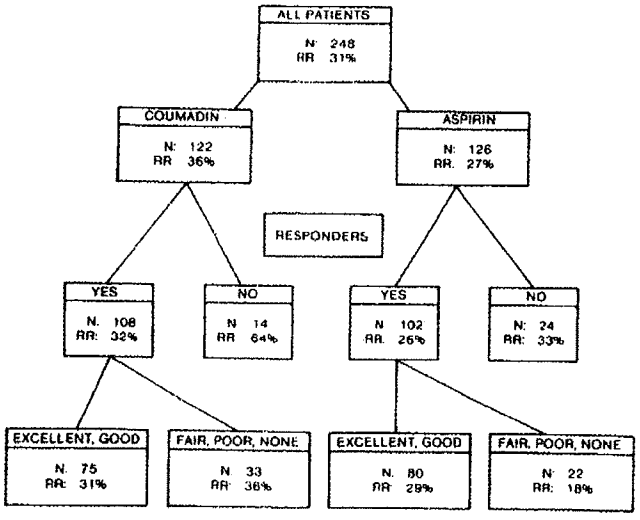

FIGURE 1. Compliance and recurrence. RR = recurrence rate.

TABLE 4
Recurrence (R) in patients with ≥ 6 months history of angina

	Coumadin	Aspirin
Total patients		
n	43	48
R	19 (44%)	10 (21%) (p < .05)
Total responders		
n	34	42
R	14 (41%)	10 (24%)
Responders on no therapy		
n	8 (24%)	6 (14%) (NS)
R	3 (38%)	2 (33%)
Responders on some therapy		
n	26	36
R	11 (42%)	8 (22%) (p < .10)

TABLE 6
Total recurrence (R)

	Coumadin	Aspirin
Total patients		
n	122	126
R	44 (36%)	34 (27%) (NS)
Total responders		
n	108	102
R	36 (33%)	25 (24%)
Responders on no therapy		
n	28 (26%)	15 (15%) (p < .05)
R	9 (32%)	3 (20%)
Responders on some therapy		
n	80	87
R	27 (34%)	22 (25%) (NS)

(8/36) on aspirin (p < .10). These findings point to an advantage of aspirin therapy over coumadin in the prevention of recurrence after PTCA in patients with at least a 6 month history of angina pectoris independent of differences in compliance (table 4). In the group of patients with a history of angina of less than 6 months, the recurrence rate was very similar between coumadin and aspirin subgroups (table 5).

An additional point regarding compliance with medication is raised by the finding that upon analysis of data from those patients in the entire sample reporting no compliance with medication, the recurrence rate was found to be 28% (12/43). Admittedly these patients may be less symptomatic and thus less willing to take medication, but the result indicates that a randomized study of PTCA patients could include a group receiving placebo (table 6).

Sample size. At the inception of the study a recurrence rate for coumadin in the range of 25% was predicted in accordance with previous European experience.[4] Since we believed that aspirin would prove to be the inferior of the two adjunctive therapies, a 35% recurrence rate with aspirin was taken to represent a clinically significant difference. Thus, it was determined that a sample size of 348 patients in each group or over 600 patients would be needed to demonstrate a statistically significant difference with a study power of 80% at the 5% probability level. On initial examination of the data in September 1981, however, it was found that coumadin therapy was associated with a higher percentage of patients with recurrent stenoses than was aspirin. This finding resulted in the termination of this study on clinical grounds. The sample size was thus limited to 248 patients. In addition, the 95% confidence interval for the difference between the two mean recurrence rates of 36% for coumadin and 27% for aspirin patients was [(−.03) to (.21)], indicating that the difference could not have favored coumadin therapy by more than 3%. Thus, even though the patient sample size is inadequate to demonstrate that aspirin is statistically significantly more beneficial that coumadin therapy in preventing recurrent stenosis, the chance of the reverse being true is very small.

TABLE 5
Recurrence (R) in patients with < 6 months history of angina

	Coumadin	Aspirin
Total patients		
n	79	78
R	25 (32%)	24 (31%) (NS)
Total responders		
n	74	60
R	22 (30%)	15 (25%)
Responders on no therapy		
n	20 (27%)	9 (15%) (p < .10)
R	6 (30%)	1 (11%) (NS)
Responders on some therapy		
n	54	51
R	16 (30%)	14 (27%) (NS)

Variables influencing recurrence rate. Discriminate analysis was performed on the raw data to determine those variables with the greatest influence on recurrence rate. Variables considered included percent stenosis and pressure gradient before and after PTCA, duration of anginal symptoms, age, and sex. No single variable or combination of variables was selected by computerized analysis with a p value approaching the usual levels of statistical significance. In addition, cross-table analysis was performed on these variables and again failed to reveal any serious imbalance between subgroups. The results of these analyses did not influence the outcome of this study.

Discussion

This report represents the first known randomized study of patients undergoing PTCA. Although it was our hypothesis that coumadin would be proven more effective as adjunctive therapy after PTCA than aspirin, the results strongly indicate that the probability of coumadin therapy being associated with a reduced recurrence rate as compared with aspirin is very small. On the contrary, aspirin therapy was shown to be associated with a statistically significant advantage as compared with coumadin in prevention of recurrence of stenosis in patients with at least a 6 month history of anginal symptoms. This result was not related to a difference in patient compliance. It is important to note that at the time this study was undertaken, randomization of patients to placebo therapy would not have been considered clinically feasible. However, given the results of this study as well as accumulated clinical information, inclusion of a placebo group may be considered in future trials.

Since the possibility of emergency bypass surgery always exists with this procedure, coumadin therapy could not be started before PTCA. Thus, those patients randomized to coumadin were placed on this therapy immediately after the procedure. Since a gap of 2 to 3 days exists between the initial administration of coumadin and the attainment of therapeutic levels, this group was at a potential disadvantage because the effect of immediate post-PTCA adjunctive therapy on late outcome is unknown. Thus, both groups were maintained on equal aspirin dosages before and immediately after the procedure until coumadin levels became therapeutic.

The study was intended to evaluate adjunctive therapy as used in this country after coronary angioplasty. The responsibility was left in the hands of the referring physician to ensure patient compliance as previously described. There is admittedly a lack of control of blood levels of coumadin or aspirin, but it was thought that the creation of an artificially controlled situation of patient monitoring would not be representative of actual practice.

The importance of this study lies not in its demonstration of any advantage of adjunctive therapy with aspirin after PTCA, but rather with the finding that coumadin therapy appears no more efficacious than aspirin therapy after angioplasty. The incidence of side effects with coumadin therapy has been well documented and exceeds that of aspirin.[16-19] Also, in the event that coronary bypass grafting be required at a later date, the risk of preoperative anticoagulation has been demonstrated.[19] In addition, this study illustrates a tendency toward decreased patient compliance with coumadin therapy, as determined by subjective assessment of referring physicians as well as by the small percentage of patients with adequate prothrombin time values. The need for a well-controlled randomized study of anticoagulation has been cited by many investigators.[20] A randomized study by Mayer et al.[21] and one by Pantely et al.[22] demonstrated an advantage to the use of aspirin in the maintenance of coronary bypass graft patency. The theoretical basis of this effect may be explained by a shortened platelet survival time in patients with coronary disease as postulated by Steele et al.,[24] who suggested that antiplatelet drugs may prolong the patency of coronary bypass grafts. Animal experiments as well as studies in vitro have described a theoretical advantage of aspirin therapy in prevention of coronary artery thrombosis.[25-27] It is interesting to speculate on the finding of significant benefit with aspirin therapy in the subgroup of patients with a longer history of anginal symptoms.

In summary, an analysis of data from a history of anginal symptoms of at least 6 months suggests that adjunctive therapy with aspirin is of significant value as compared with coumadin therapy in patients with a longer duration of anginal symptoms. Coumadin does not appear to be any more advantageous than aspirin in the prevention of recurrence of stenoses in patients after PTCA. Since there are numerous side effects of coumadin therapy, it should not be considered to be the preferred therapy after PTCA.

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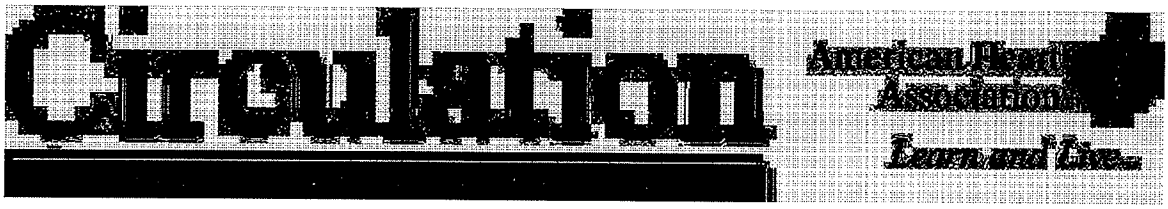

Analysis of coronary angioplasty practice in the United States with an insurance-claims data base

EJ Topol, SG Ellis, DM Cosgrove, ER Bates, DW Muller, NJ Schork, MA Schork and FD Loop

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Analysis of Coronary Angioplasty Practice in the United States With an Insurance-Claims Data Base

Eric J. Topol, MD; Stephen G. Ellis, MD; Delos M. Cosgrove, MD; Eric R. Bates, MD; David W.M. Muller, MBBS; Nicholas J. Schork, MA; M. Anthony Schork, PhD; and Floyd D. Loop, MD

Background. **Coronary angioplasty is frequently performed in the United States, with more than 300,000 procedures in 1990. Despite the high rate of use of the procedure, there have been few studies addressing practice patterns.**

Methods and Results. **From a private insurance claims data base of 5.4 million individuals, a total of 2,101 patients who underwent coronary angioplasty during 1988–1989 were identified. Using their 4,578 hospital admission records and 87,578 outpatient claim records, with an average follow-up of 332±182 days, we compared patients' outcomes and charges according to whether they had an exercise stress test before the procedure, by sex, by region of the country, and by whether the angioplasty was performed in an institution with a training program. Only 29% of the study cohort had exercise testing before angioplasty; patients in the West ($p=0.001$), those undergoing multivessel angioplasty ($p=0.00001$), and those whose procedures were performed at sites with training programs ($p=0.04$) were more likely to have a screening test, whereas women ($p=0.008$) and those with a recent myocardial infarction ($p=0.00001$) were less likely to have a screening test. The average length of stay for patients without myocardial infarction as a primary diagnosis was 5.6 days, with a total hospital charge of $15,027. In follow-up, 15.1% had coronary artery bypass surgery and 15% had at least one additional angioplasty procedure; the average follow-up charges were $4,879. Charges varied according to sex, region of the country, and academic status of the angioplasty institution. Certain outcomes showed variation by region of the country and academic status of the angioplasty institution.**

Conclusions. **The relative lack of an objective definition of myocardial ischemia and the marked variability of use of procedures according to geographic region suggest the need for further implementation of established guidelines. (*Circulation* 1993;87:1489–1497)**

KEY WORDS • angioplasty • cost analysis • sex • geographic region

Coronary revascularization with balloon angioplasty was first introduced in the United States in 1978; within 12 years, there has been such remarkable growth in the use of this technique that over 300,000 procedures were performed in 1990.[1,2] Balloon dilatation is successful in 85–90% of patients for improving the coronary arterial luminal caliber but is limited by abrupt vessel closure in the periprocedural phase and restenosis during 6-month follow-up.[3] In a recent randomized trial for patients with one-vessel coronary artery disease, angioplasty compared favorably with medical therapy for improvement of exercise capacity.[4] For multivessel disease, several randomized trials of angioplasty versus bypass surgery are presently under way, but results of these studies will not be available for at least 2–3 years.[5] In the meantime, the American Heart Association and the American College of Cardiology have published guidelines for the use of coronary angioplasty.[6] For example, in patients with stable angina, the guidelines state that for angioplasty to be performed, there must be "objective evidence of myocardial ischemia while on medical therapy during

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laboratory testing."[6] Whether such guidelines have been generally adopted remains unclear. The purpose of the present study was to describe angioplasty practice patterns in the United States. To date, no such studies have been completed. Using a large private insurance claims data base, we focused on indications for angioplasty procedures, specifically whether an exercise test preceded the angioplasty, geographic variability in angioplasty practice, sex differences, the effect of training programs, and associated charges.

Methods

Data Base and Patient Population

For this study, we used a data base (MEDSTAT Systems, Ann Arbor, Mich.) comprising all the health

From the Departments of Cardiology (E.J.T., S.G.E.) and Thoracic and Cardiovascular Surgery (D.M.C., F.D.L.), the Cleveland Clinic Foundation (Ohio), and the Departments of Biostatistics, School of Public Health (M.A.S.), and Medicine (E.R.B., D.W.M.M., N.J.S.), the University of Michigan, Ann Arbor.

Address for reprints: Eric J. Topol, MD, Department of Cardiology, F25, The Cleveland Clinic Foundation, 9500 Euclid Avenue, Cleveland, OH 44195.

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TABLE 1. Comparison of Patients With and Without Exercise Testing Before Coronary Angioplasty

	No exercise test			Exercise test			*p*
No.	1,495			606			
Age (years, mean±SD)	53.7±7.2			54.3±7.0			
Sex (%)							
Female	21.9			18.0			0.04
Male	78.1			82.0			
Training program (%)							
Yes	6.8			9.5			0.04
No	93.2			90.5			
Region (%)							
Northeast	11.3			14.0			0.002
Midwest	49.1			44.2			
South	25.5			22.2			
West	14.2			19.6			
Diagnosis (%)							
Myocardial infarction	18.9			4.6			<0.0001
Unstable angina	12.4			14.2			
Angina	68.7			81.2			
Type of coronary angioplasty (%)†							
One-vessel	96.1			95.7			
Multivessel	3.9			4.3			
Prior PTCA (%)	1.9			7.8			
Outcomes*							
Myocardial infarction	5.2			5.8			
Repeat PTCA	17.7			21.8			
CABG	12.4			15.1			
	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	
Length of stay (days)	3	6	9	2	3	6	<0.01
Charges (dollars)							
Hospital	8,303	12,486	18,280	6,318	9,402	14,781	<0.0001
Professional	3,175	4,210	5,587	2,910	3,837	5,188	<0.001
Total	11,810	16,667	22,967	9,323	13,214	19,554	<0.0001
Follow-up	1,694	4,800	14,690	1,425	5,075	14,438	

PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass surgery.
*Rates (number of patients per 100 per year) adjusted for length of follow-up. †During a single sitting.

insurance claims of 5.4 million privately insured individuals with an accumulated 172 million medical claims. The patients forming the data base are employees or dependents of employees of more than 70 large American companies, which represents a 6% sample by expenditure of all privately insured health care in the United States. The insurance coverage provided is comprehensive, with no copayment requirement. The data base was selected for its uniformity, completeness, and prior use in establishing practice patterns among radiologists.[7] The same data base was recently used to confirm a report on the gender gap in performance of coronary revascularization procedures in this country.[8] The patient population is distributed nationally and categorized to four geographic regions: 1) 19% in the Northeast, which comprises Connecticut, Maine, Massachusetts, New Hampshire, Rhode Island, Vermont, New Jersey, New York, and Pennsylvania; 2) 34% in the Midwest, consisting of Illinois, Ohio, Indiana, Michigan, Wisconsin, Iowa, Kansas, Minnesota, Nebraska, North Dakota, South Dakota, and Missouri; 3) 30% in the South, including Washington, D.C., Delaware, Florida, Georgia, Maryland, North Carolina, South Carolina, Virginia, West Virginia, Alabama, Kentucky, Mississippi, Tennessee, Arkansas, Louisiana, Oklahoma, and Texas; and 4) 17% in the West, consisting of Arizona, Colorado, Idaho, Montana, Nevada, New Mexico, Utah, Wyoming, Alaska, California, Oregon, Washington, and Hawaii.

TABLE 2. Multiple Logistic Regression Model for Exercise Test Before Index Coronary Angioplasty

Significant covariates	Coefficients	*p*
Female sex	−0.17	0.008
MI before index PTCA	−0.79	0.00001
Training program	+0.20	0.04
Western region	+0.21	0.001
Multivessel PTCA	+0.74	0.00001

MI, myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty.

In the complete data base, 56% of patients were <35 years old, 19% were 35–44 years old, 14% were

TABLE 3. Comparison Between Patient Groups by Training Program

	No training program			Training program			*p*
No.	1,720			140			
Age (years)	53.9			54.1			
Sex (%)							
Female	20.9			22.1			
Male	79.1			77.9			
Region (%)							
Northeast	11.0			25.9			
Midwest	49.2			51.1			<0.0001
South	22.9			19.4			
West	16.9			3.6			
Diagnosis (%)							
Myocardial infarction	15.6			10.0			
Unstable angina	13.4			12.1			0.02
Angina	71.0			77.8			
Exercise test (%)	27.8			35.7			0.04
One-vessel PTCA (%)	95.8			95.0			
Multivessel PTCA (%)	4.2			5.0			
Prior PTCA (%)	3.8			3.1			
Outcomes*							
Myocardial infarction	5.3			7.5			
Repeat PTCA	17.6			28.4			0.02
CABG	14.6			9.5			
Length of stay (days)	6.2			4.7			0.02
	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	
Charges (dollars)							
Hospital	7,854	11,831	17,453	5,654	8,460	13,253	
Professional	3,117	4,089	5,506	2,735	3,340	4,498	
Total	11,219	16,220	22,349	8,489	11,905	17,647	
Follow-up	1,634	4,807	14,523	1,437	5,067	13,525	

PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass surgery.
*Rates (number of patients per 100 per year) adjusted for length of follow-up.

45–54 years old, and the remaining 11% were 55–64 years old. No patients 65 years of age or older were included to avoid incomplete claims experience caused by coexisting Medicare coverage. In addition to the exclusion of patients with Medicare, no patients with Medicaid or Worker's Compensation are included in the data base.

A data base relevant to coronary angioplasty practice was created by identifying patients who had a medical claim for this procedure, defined as International Classification of Diseases, 9th Revision, Clinical Modification (ICD-9-CM codes)[9] 36.0, 36.01, 36.02, 36.05, and 36.09 and/or CPT-4 codes 92982 or 92984[10] during the time period April 1, 1988, through December 31, 1989. Once these patients were identified, all of their inpatient and outpatient claims for services incurred 90 days before or anytime after the initial coronary angioplasty (until December 31, 1989) were selected for inclusion in the data base. The reason for the 90-day background period for every patient was to establish what tests had been performed before the index coronary angioplasty. The "index" coronary angioplasty procedure was defined as the first one performed on or subsequent to April 1, 1988.

TABLE 4. Length of Stay for Index Coronary Angioplasty: Results From Multiple Regression Analysis

Significant covariates*	Standardized coefficients†	*p*
Female sex	+0.09	0.00001
Northeastern region	+0.07	0.003
Midwestern region	−0.06	0.01
Western region	−0.15	0.0001
Training program	−0.09	0.00001
MI before index PTCA	+0.21	0.0001
Angina before index PTCA	−0.06	0.007
Prior exercise test	−0.19	0.00001
Multiple vessels	0.04	0.04

MI, myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty.
Covariables available for selection into model were age, sex, exercise test before index PTCA, region (Northwest, Midwest, South, West), training program, diagnosis before index PTCA (MI, unstable angina, angina, other), one-vessel or multivessel PTCA, and PTCA in 3 months before index PTCA.
*Significant, $p<0.05$.
†Minus sign indicates that the predictor would be less likely to result in an increase in the outcome for patients with this characteristic; plus sign indicates more likely.

TABLE 5. Hospital and Professional Charges for Index Coronary Angioplasty: Results From Multiple Regression Analysis

Significant covariates*	Standardized coefficients†	p
Age	+0.09	0.00001
Female sex	+0.05	0.03
Training program	−0.08	0.0002
Prior exercise test	−0.10	0.00001
Western region	+0.11	0.00001
Midwestern region	−0.08	0.0004
MI before index PTCA	+0.20	0.00001
Angina before index PTCA	−0.06	0.002
PTCA before index PTCA	−0.04	0.05

MI, myocardial infarction; PTCA, percutaneous transluminal coronary angioplasty.

Covariables available for selection into model were age, sex, exercise test before index PTCA, region (Northwest, Midwest, South, West), training program, diagnosis before index PTCA (MI, unstable angina, angina, other), one-vessel or multivessel PTCA, and PTCA in 3 months before index PTCA.

*Significant, $p<0.05$.

†Minus sign indicates that the predictor would be less likely to result in an increase in the outcome for patients with this characteristic; plus sign indicates more likely.

Data Analysis

The coronary angioplasty data were analyzed by four different categorizations. First, patients were divided into two groups according to whether or not they underwent an exercise stress test before their index coronary angioplasty procedure. The exercise stress test was defined as either an inpatient or outpatient procedure, using appropriate ICD-9-CM codes, with or without thallium scintigraphy, echocardiography, or gated cardiac blood pool imaging. The data for whether or not an exercise test was performed are comprehensive; if a claim was submitted for any of these diagnostic tests in the 3 months before the index angioplasty, it was tallied. Second, hospital sites at which the procedures were performed were classified as having a training program if an approved American College of Cardiology fellowship program was operational at the site during the time frame used to create the data base. The American College of Cardiology–approved programs[11] are not strictly university sites, and these programs are not specifically approved for coronary interventional training. Third, the data base was analyzed by the four geographic regions stipulated earlier. Fourth, patients were studied by sex.

For all analyses, data such as age, prior coronary angioplasty, and whether a one-vessel or multivessel angioplasty was performed were available. For this study, a follow-up myocardial infarction (ICD-9-CM codes 410-412) was defined as no myocardial infarction in the 3 months before the index angioplasty and no infarction as the precipitating diagnosis. The follow-up outcomes of myocardial infarction, coronary artery bypass surgery, repeat coronary angioplasty, and duration of follow-up were tallied. Available charge data included total hospital charges for the admission, which included the index coronary angiogram and angioplasty, professional charges, the total of the index coronary angioplasty hospital and professional charges, and the cumulative (hospital and physician) charges during the follow-up phase. Procedures and diagnoses were defined by appropriate ICD-9-CM and CPT-4 codes.[9,10]

Statistical Methods

All continuous measures are expressed as mean±SD except length of stay and financial variables, which, because of their highly skewed distributions, are presented as medians with the 25th and 75th quartiles. Dichotomous variables are presented as percentages. Tests of hypotheses were considered significant if their associated probability values were less than 0.05. Univariate analyses for comparison of patient characteristics among the subgroups defined by the four primary characterizations (treadmill testing, cardiology training program, geographical region, and sex) used χ^2 tests for dichotomous variables, t tests or ANOVA for continuous measures, a Mann-Whitney or Kruskal-Wallis test for length of hospital stay and the cost of variables (highly skewed distributions), and a Kaplan-Meier survival analysis with the log-rank statistic for outcome variables (myocardial infarction, bypass surgery, and repeat angioplasty).[12] Because of the variability in the length of follow-up for outcome variables, for ease of understanding, the rates presented in the tables are adjusted for length of follow-up within each subgroup on a per annum basis, i.e., rates are per 100 subjects per year.[12]

Multiple logistic regression was used to identify the significant predictors associated with having an exercise test in the 3 months before the index coronary angioplasty. Significant predictors for the log-transformed length of stay and for the log-transformed hospital charges associated with the index coronary angioplasty were determined by multiple linear regression analysis. A stepwise, multivariable log-rank test procedure was used to determine the significance of covariates and two-factor interactions associated with time from the index coronary angioplasty to each of the outcome variables separately. The set of covariates available for selection into the various models included age, sex, exercise test status before index angioplasty, geographic region, training program status, precipitating diagnosis, one-vessel or multivessel angioplasty, and presence or absence of angioplasty in the 3 months antedating the index angioplasty procedure and all possible two-factor interactions.

Results

Patient Population

A total of 2,101 patients who underwent coronary angioplasty constitute the data base. A total of 4,578 hospital admission records, 60,974 inpatient service records, and 87,578 outpatient claim records were available for these patients. The mean age of the patients was 53.9±7.2 years. Women constituted 20.7% of the patients, and only 3.6% had coronary angioplasty in the 3 months before the index procedure. The primary diagnoses are recent acute myocardial infarction (312 patients [14.8%]), unstable angina (272 patients [12.9%]), and stable angina or coronary artery disease (1,517 patients [72.2%]). Of note, only 4% of patients underwent multivessel coronary angioplasty during the index procedural hospitalization. The average length of

TABLE 6. Comparison Between Groups Categorized by Geographic Region for Patients With PTCA

	Northeast			Midwest			South			West			*p*
No.	239			987			507			326			
Age (years, mean)	54.2			53.5			54.3			54.3			
Prior PTCA (%)	2.4			4.4			3.5			2.8			
Diagnosis (%)													
Myocardial infarction	9.2			14.7			17.5			16.6			0.007
Unstable angina	12.0			14.2			12.0			11.3			
Angina	78.7			71.1			70.5			72.1			
Exercise test (%)	32.9			26.2			25.6			35.3			0.002
Training program (%)	16.1			7.8			6.4			1.7			<0.0001
One-vessel PTCA (%)	95.2			96.1			96.9			94.2			
Multivessel PTCA (%)	4.8			3.9			3.1			5.8			
Length of stay (days)	7.8			6.0			6.5			4.6			
Outcomes*													
Myocardial infarction	5.8			4.7			7.4			4.5			
Repeat PTCA	16.0			18.1			20.5			19.9			
CABG	10.1			14.1			15.5			19.1			
	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	
Charges (dollars)													
Hospital	7,064	10,672	16,598	6,643	10,518	16,044	8,336	12,209	17,397	9,510	14,484	24,227	
Professional	2,710	3,932	5,675	2,912	3,848	4,956	3,261	4,397	5,648	3,544	4,725	7,015	
Total	9,914	14,870	20,734	4,799	14,517	20,644	12,216	16,552	22,412	14,158	19,026	30,874	
Follow-up	1,955	4,896	10,916	1,683	4,800	13,949	1,282	4,446	14,629	1,875	5,325	19,437	

PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass surgery.
*Rates (number of patients per 100 per year) adjusted for length of follow-up.

follow-up time available was 332 days. Over the course of the follow-up, 15.1% of the patients (Figure 1) underwent coronary artery bypass surgery. Approximately one third of these patients were operated on emergently or within 7 days after the index coronary angioplasty. In addition, 15% went on to have an additional percutaneous transluminal coronary angioplasty (PTCA) procedure, and 4.6% had a myocardial infarction subsequent to the index angioplasty. Of the 316 patients who went on to have repeat angioplasty, 255 (80.7%) had a total of two procedures, 48 (15.2%) had three procedures, 12 (3.8%) had four procedures, and one (0.3%) had five angioplasty procedures.

Exercise Testing Before Coronary Angioplasty

In Table 1, summaries of information for patients divided according to whether or not their angioplasty procedure was preceded by an exercise test are presented. Patients with an exercise test before the index coronary angioplasty composed 29% of the study cohort and differed from the majority of patients without a functional test by sex, geographic region, training program status, and diagnosis. Of note, only 9.0% of patients with a recent myocardial infarction underwent an exercise test before coronary angioplasty. By multiple logistic regression (Table 2), factors positively associated with a prior exercise test included the index angioplasty being performed in a hospital with a cardiology training program, the western region of the country, and multivessel angioplasty, whereas being a woman and having had a recent myocardial infarction were two factors significantly and negatively associated with having an exercise test before coronary angioplasty.

Patients with or without prior exercise testing had similar long-term outcomes with respect to repeat angioplasty, bypass surgery, and myocardial infarction. However, those with a prior exercise test had a significantly shorter hospital stay (median, 3 versus 6 days; $p<0.01$) and less expensive hospital, professional, and total charges. Of note, the median charge for the exercise test was $180 (25th quartile, $125; 75th quartile, $225).

Angioplasty Practice and Charges by Training Program

More than one third (34%) of US cardiology training programs[11] are represented in the data base. There were disproportionately more cardiology training programs in the northeastern region of the United States (Table 3). Patients in training program hospitals were

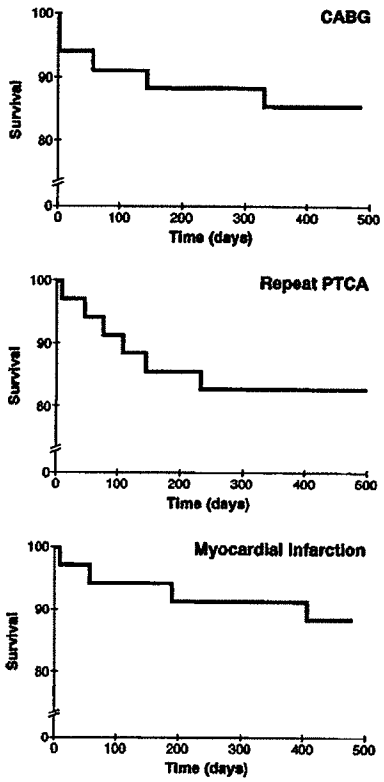

FIGURE 1. *Time/survival graphs. Top panel: Frequency and timing of crossover to coronary artery bypass surgery (CABG) after the index coronary angioplasty procedure by survival analysis (proportion of patients without outcome). Three covariates were significantly associated with an increase of bypass surgery in follow-up: older age (p=0.007), the combination of older age and diagnosis of unstable angina (p=0.02), and western region (p=0.05). Middle panel: Frequency and timing of recurrent percutaneous transluminal coronary angioplasty (PTCA) after the index coronary angioplasty procedure by survival analysis. Three covariates were significantly associated with an increase in recurrent PTCA: a training program in the southern region (p=0.006), a diagnosis of unstable angina (p=0.02), and older age in combination with a diagnosis of unstable angina (p=0.03). Bottom panel: Frequency and timing of myocardial infarction (MI) or recurrent MI after the index coronary angioplasty procedure by survival analysis. Three covariates were significantly associated with an increase of recurrent MI in follow-up: a diagnosis of unstable angina (p=0.04), female sex with unstable angina (p=0.003), and older age in combination with the southern region (p=0.03).*

more likely to have a repeat angioplasty, more frequently had angina, and were less likely to have had a diagnosis of recent myocardial infarction. Their hospital stay was more abbreviated and associated with lower hospital and professional charges. These findings were confirmed by multiple regression analyses, which showed that training program patients had a briefer hospital stay (p=0.0001) and lower total charges (p=0.0001) (Tables 4 and 5).

Angioplasty Practice by Geographic Region

The Midwest accounted for 34% of the overall MEDSTAT data base population but 48% of the angioplasty cohort (Table 6). The relative proportion of patients for the other regions in this angioplasty cohort and overall data base are for the Northeast, 19% and 12%, respectively; for the South, 30% and 24%, respectively; and for the West, 17% and 16%, respectively. There were no differences in key baseline demographic characteristics, such as age and sex, or by geographic region in the overall population. Along with this preponderance of angioplasty procedures in the Midwest, the use of exercise testing tended to be lower in this region than in two of the other regions.

Patients in the Northeast had the longest hospitalization stays but among the least in total charges. By multiple regression analysis for length of stay, the Northeast was significantly associated with an increased duration, whereas the Midwest and the West were associated with a decreased length of stay (Table 4). The use of subsequent bypass surgery was highest in the West. As described in the legend in Figure 1, this region was associated with an increased use of bypass surgery. In addition, the western region was significantly associated with increased index hospital and professional charges (Table 6).

Sex Differences

Women in the angioplasty cohort tended to be older, less likely to have myocardial infarction or unstable angina, and to have an increased length of hospital stay and higher charges compared with men (Table 7). As shown in Table 2, female sex was associated with lack of an exercise test before angioplasty. Female sex also proved to be significantly associated with increased hospital stay and higher charges by multiple regression analysis (Tables 4 and 5).

Factors Associated With Clinical Outcomes

Figure 1 shows the Kaplan-Meier survival curve computed for each of the clinical outcomes. The associates of each of the outcome variables were assessed via multivariable log-rank procedures and are described below and summarized in the legends to Figure 1. For myocardial infarction, a precipitating diagnosis for the index coronary angioplasty of unstable angina, women with unstable angina and older age in combination with the southern region were significantly and positively associated with the occurrence of post-PTCA myocardial infarction. If only main effects without interactions are considered, then a precipitating diagnosis for the index coronary angioplasty of unstable angina and being a patient in the South were significant and positive predictors of myocardial infarction. For recurrent angioplasty, a diagnosis of unstable angina, the combination of older age and a diagnosis of unstable angina, and the combination of having a training program and being in the South were each significantly and positively associated with the repeat coronary angioplasty. For the model with main effects only, whether the hospital had a cardiology training program and whether the precipitating diagnosis for the index angioplasty was unstable

TABLE 7. Comparison Between Groups Categorized by Sex for Patients With Coronary Angioplasty

	Men			Women			*p*
No.	1,664			437			
Age (years, mean±SD)	53.6±7.4			55.0±8.1			0.0009
Exercise test (%)	29.9			24.6			0.02
Diagnosis (%)							
Myocardial infarction	15.7			11.3			
Unstable angina	21.1			6.0			0.02
Angina	72.1			82.7			
Region (%)							
Northeast	11.8			12.9			
Midwest	46.6			51.6			
South	25.2			22.1			
West	16.4			13.4			
One-vessel PTCA (%)	95.7			96.8			
Multivessel PTCA (%)	4.3			3.2			
Prior PTCA (%)	3.2			5.2			
Training program (%)	7.4			7.9			
Length of stay (days)	5.9			7.3			0.0001
Outcomes*							
Myocardial infarction	5.4			4.9			
Repeat PTCA	18.3			18.6			
CABG	14.1			17.6			
	25th Quartile	Median	75th Quartile	25th Quartile	Median	75th Quartile	
Charges (dollars)							
Hospital	7,806	11,423	16,817	7,443	12,304	19,145	
Professional	3,076	4,035	5,402	2,919	4,225	5,808	
Total	10,954	15,782	21,783	10,809	16,607	23,695	
Follow-up	1,512	4,512	13,844	2,381	5,874	16,776	

PTCA, percutaneous transluminal coronary angioplasty; CABG, coronary artery bypass surgery.
*Rates (number of patients per 100 per year) adjusted for length of follow-up.

angina or angina were each significantly and positively associated with the repeat coronary angioplasty. The significantly and positively associated factors for bypass surgery after the index angioplasty were older age, living in the West, and the combination of older age and a diagnosis of unstable angina. When main effects only are considered, older age, living in the West, and a diagnosis of unstable angina were the significant and positive predictors of bypass surgery.

Discussion

In 1988, coronary angioplasty in the United States was performed at a rate of 1,000 per million population, compared with 390 in Belgium, 256 in Australia, and 233 in Germany.[13] With over 350,000 procedures expected to be done in the United States in 1991, at an average charge of $16,000 to third-party carriers, this accounts for approximately $5.6 billion for initial hospitalization and, at $5,000 for 1-year follow-up charges, an additional $1.6 billion in a 12-month period. With the increased need for scrutiny of our health care costs, it is vital to study such important medical procedures as angioplasty, which have a critical impact not only on cardiovascular health but also on the economy.

The use of a medical claims private insurance data base as in the present study is somewhat limited owing to a lack of complete baseline demographics and comorbidities, actual results for the exercise tests, lack of technical or procedural data, and a dependence on fiscal triggering for definition of medical outcomes. For example, although mortality in the present cohort would be expected to be low (<2%),[3] it was not possible to reliably identify fatal events. The reliability of the data for the performance of an exercise test before coronary angioplasty is directly related to the physician's billing for the test. Because it is unlikely that procedures would be performed but not billed, capture of virtually all exercise and functional testing within 3 months of the index angioplasty is ensured.

We acknowledge the important potential limitations of the use of a privately insured, relatively young population. However, the large population of younger, predominantly working, insured individuals provides a window into the health care practices of the private insurance industry. During 1988, in the population <65 years old, 73% were privately insured.[7] The ability to capture all in-hospital cumulative charges, for which there is a 96% correlation to actual insurance carrier payments (unpublished data, MEDSTAT), is a unique strength of the data base. Furthermore, young, working patients are more likely to be candidates for an exercise test, so the use of exercise testing before coronary angioplasty may actually have been overestimated in this analysis. Thus, we believe the data are quite repre-

sentative of a cross section of angioplasty practice in this country.

The 1-year outcome data of subsequent myocardial infarction and coronary revascularization procedures are remarkably consistent with those of the National Heart, Lung, and Blood Institute (NHLBI) 1985–1986 Registry of coronary angioplasty.[3] The NHLBI Registry is not nationally representative, consisting of only 16 clinical sites, but it is the only available previous report of angioplasty practice patterns.[3] In this Registry of 1,802 patients, the average age was 57.7 years, 26% women, compared with an average age of 53.9 years, 21% women, in the present study. Of note, the NHLBI rates of subsequent myocardial infarction (4.3%), bypass surgery (15%), and repeat angioplasty (15%) closely approximate follow-up outcomes in the present study.

In many respects, the results of our analyses are not what we had anticipated. Although there are several ongoing randomized trials of multivessel coronary angioplasty,[5] 96% of patients in the present cohort underwent a one-vessel procedure. Despite this relative lack of complex anatomy, the average length of stay exceeded 5 days, average initial hospital and professional charges accumulated to >$15,000, and within 1 year >15% of patients had been referred to coronary artery bypass surgery and another 15% had repeat coronary angioplasty. Restenosis after successful balloon angioplasty is the paramount limitation of the procedure[14,15] and the most likely explanation for subsequent coronary revascularization procedures in nearly one third of patients.

The high prevalence of coronary angioplasty procedures without antecedent exercise testing is quite unexpected. Although preprocedural demonstration of myocardial ischemia is stipulated as necessary in the American College of Cardiology and American Heart Association guidelines,[6] only 29% of patients underwent such testing in the 3 months before the index angioplasty. The finding demonstrates the practice of performing angioplasty primarily on the basis of coronary anatomic findings.[16] In addition, comparison with the baseline exercise test is extremely helpful for assessing improvement in or recurrence of myocardial ischemia after the angioplasty procedure.

The characteristics of the patients who did not have exercise testing before angioplasty included female sex and a diagnosis of recent myocardial infarction. Thus, our data extend the recent findings of Ayanian and Epstein,[17] who reported discordant coronary revascularization practices according to sex. Moreover, several randomized trials of balloon coronary angioplasty after thrombolytic therapy for acute myocardial infarction have indicated the lack of need for this procedure if a patient is free of ischemic symptoms or has a negative exercise test.[18–20] Our finding that only 9.0% of patients with a primary diagnosis of recent myocardial infarction had an exercise test in the 3 months before coronary angioplasty is important and remains at odds with the results of pivotal clinical trials. Although one would not expect exercise testing to be performed in patients with unstable angina, the majority of patients did not have this as their primary diagnosis. Interestingly, patients with prior exercise testing had a significantly decreased length of stay and hospital cost.

There was substantial geographic variability in angioplasty practice throughout the United States. It was ironic to find that the region with the greatest length of stay was among those with the lowest cumulative charges. Although the western region charges were the highest, this patient group was most likely to have exercise testing before the procedure and had the shortest hospital stay. The lack of concordance between regions for such important indexes as preprocedural screening, length of stay, use and type of subsequent coronary revascularization procedures, and charges indicates that considerable variance exists in how the procedure is currently practiced and a lack of standardization. Similar findings from a Medicare data base have been published for coronary artery bypass surgery.[21,22]

Although only 8% of the procedures in the angioplasty data base were performed in institutions with cardiovascular training programs, their impact was noteworthy. Not only was there an increased likelihood of exercise testing before the procedure, but patients treated in these centers had a relatively short hospital stay and reduced charges. In many hospitals with cardiology training programs, patients with uncomplicated coronary angioplasty are admitted to the hospital the day of the procedure and discharged within 24 hours. For improvement in the cost-effectiveness of coronary angioplasty, a regional approach involving cardiovascular training programs appears to deserve further study.

This analysis of contemporary coronary angioplasty practice in the United States has been instructive in that it highlights the large proportion of patients without objective definition of myocardial ischemia undergoing the procedure and points out variability in practice with respect to patient sex as well as the geographic location and academic status of hospital sites. With more than $8 billion of health care charges per year for coronary angioplasty procedures in this country, it behooves us to carefully scrutinize selection criteria, procedural and long-term outcomes, and key economic parameters. Although coronary angioplasty represents one of the most significant advances in cardiovascular medicine in the 1980s, it will be important to implement more effective use in the present decade.

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A COMPARISON OF DIRECTIONAL ATHERECTOMY WITH CORONARY ANGIOPLASTY IN PATIENTS WITH CORONARY ARTERY DISEASE

ERIC J. TOPOL, M.D., FERDINAND LEYA, M.D., CASS A. PINKERTON, M.D., PATRICK L. WHITLOW, M.D., BERTHOLD HOFLING, M.D., CHARLES A. SIMONTON, M.D., RONALD R. MARDEN, M.D., PATRICK W. SERRUYS, M.D., PH.D., MARTIN B. LEON, M.D., DAVID O. WILLIAMS, M.D., SPENCER B. KING, III, M.D., DANIEL B. MARK, M.D., M.P.H., JEFFREY M. ISNER, M.D., DAVID R. HOLMES, JR., M.D., STEPHEN G. ELLIS, M.D., KERRY L. LEE, PH.D., GORDON P. KELLER, M.S., LISA G. BERDAN, P.A.-C., M.H.S., TOMOARI HINOHARA, M.D., AND ROBERT M. CALIFF, M.D., FOR THE CAVEAT STUDY GROUP*

Abstract *Background.* Directional coronary atherectomy is a new technique of coronary revascularization by which atherosclerotic plaque is excised and retrieved from target lesions. With respect to the rate of restenosis and clinical outcomes, it is not known how this procedure compares with balloon angioplasty, which relies on dilation of the plaque and vessel wall. We compared the rate of restenosis after angioplasty with that after atherectomy.

Methods. At 38 sites in the United States and Europe, 1012 patients were randomly assigned to either atherectomy (512 patients) or angioplasty (500 patients). The patients underwent coronary angiography at base line and again after six months; the paired angiograms were quantitatively assessed at one laboratory by investigators unaware of the treatment assignments.

Results. Stenosis was reduced to 50 percent or less more often with atherectomy than with angioplasty (89 percent vs. 80 percent, $P<0.001$), and there was a greater immediate increase in vessel caliber (1.06 vs. 0.86 mm, $P<0.001$). This was accompanied by a higher rate of early complications (11 percent vs. 5 percent, $P<0.001$) and higher in-hospital costs ($11,904 vs. $10,637; $P = 0.006$). At six months, the rate of restenosis was 50 percent for atherectomy and 57 percent for angioplasty ($P = 0.06$). However, the probability of death or myocardial infarction within six months was higher in the atherectomy group (8.6 percent vs. 4.8 percent, $P = 0.007$).

Conclusions. Removing coronary artery plaque with atherectomy led to a larger luminal diameter and a small reduction in angiographic restenosis, the latter being confined largely to the proximal left anterior descending coronary artery. However, atherectomy led to a higher rate of early complications, increased cost, and no apparent clinical benefit after six months of follow-up. (N Engl J Med 1993;329:221-7.)

DIRECTIONAL coronary atherectomy was developed by Simpson in 1984, and unlike balloon angioplasty, it allows the resection of coronary atherosclerotic plaque. From October 1986 through December 1989, 1020 procedures were performed at 14 investigational sites in the United States, with a success rate of 85 percent.[1] As a result, in September 1990 atherectomy was approved by the Food and Drug Administration for coronary revascularization. The procedure has since become widely used in the United States. In 1991, approximately 17,000 coronary-atherectomy procedures were performed, and it is estimated that in 1992 nearly 33,000 procedures were done, accounting for 10 percent of all nonsurgical coronary-revascularization procedures in the country.[2]

Balloon coronary angioplasty has a high rate of restenosis (30 to 50 percent), which detracts from its long-term success.[3] If the procedure involved removing part of the coronary lesion rather than stretching the diseased segment, it is theoretically possible that the restenosis rate could be reduced. In this randomized, multicenter trial, we tested the hypothesis that

From the Cleveland Clinic Foundation, Cleveland (E.J.T., R.L.W., S.G.E.); Loyola Medical Center, Chicago (F.L.); St. Vincent's Hospital, Indianapolis (C.A.P.); Klinikum Grosshadern der Universität, Munich, Germany (B.H.); Carolinas Medical Center, Charlotte, N.C. (C.A.S.); Jewish Hospital, Louisville, Ky. (R.R.M.); Erasmus University, Rotterdam, the Netherlands (P.W.S.); Washington Cardiology Center, Washington, D.C. (M.B.L.); Rhode Island Hospital, Providence (D.O.W.); Emory University Hospital, Atlanta (S.B.K.); Duke University Medical Center, Durham, N.C. (D.B.M., K.L.L., G.P.K., L.G.B., R.M.C.); St. Elizabeth's Hospital, Boston (J.M.I.); Mayo Foundation, Rochester, Minn. (D.R.H.); and Sequoia Hospital, Redwood City, Calif. (T.H.). Address reprint requests to Dr. Topol at the Department of Cardiology, Cleveland Clinic Foundation, Desk FF3, 9500 Euclid Ave., Cleveland, OH 44195.

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*The members of the Coronary Angioplasty versus Excisional Atherectomy Trial (CAVEAT) investigators and study groups are listed in the Appendix.

atherectomy would lead to a lower rate of restenosis than angioplasty, and we prospectively collected information about clinical, procedural, and economic outcomes.

Methods

Study Sites and Operators

The participating hospitals and investigators were selected on the basis of experience with both coronary angioplasty and atherectomy, as well as familiarity with clinical investigation in interventional cardiology. Thirty-five sites were chosen, 32 in the United States and 3 in Europe (the sites and investigators are listed in the Appendix). Each operator was required to have performed more than 400 coronary-angioplasty procedures with a success rate above 95 percent and more than 50 atherectomy procedures with a success rate above 80 percent; the protocol was reviewed and approved by the institutional review board at each site.

Patient Selection

Patients who had symptomatic ischemic heart disease deemed suitable for either atherectomy or angioplasty and who were willing to give informed consent to participate were considered for enrollment in the trial. The angiographic criteria for inclusion were the presence of discrete native coronary vessels that had not undergone previous coronary intervention, that had stenosis of at least 60 percent on visual assessment and a lesion length of 12 mm or less, and that were suitable for either a 8-French outer or larger or a 3.0-mm balloon or larger. Patients with multivessel coronary disease were eligible, but a single vessel was specified as the target before the coronary intervention began. All the lesions in the target artery had to be amenable to both interventional techniques to allow conformity with assignment to a single treatment.

To ascertain the denominator of patients being screened for participation in the trial, a log was maintained at each site that included every atherectomy procedure performed. A sample of the "universe" of all coronary interventional procedures performed at the study sites was culled during our work of active enrollment.

Randomization

After informed consent was given, the randomization center at Duke University was contacted through a telephone service that was in continuous operation. After a screening interview to document the patient's clinical and angiographic eligibility for the trial, a random assignment to either atherectomy or angioplasty was made. The randomization sequence was developed on a site-by-site basis in blocks of 12 treatment assignments so that approximately equal numbers of patients would be assigned to each treatment at each site.

Revascularization Procedures

The investigators agreed, as part of the protocol, ideally to obtain a final angiographic result with as little residual stenosis as possible. The goal was residual stenosis of less than 30 percent, although technical success has conventionally been defined as stenosis of 50 percent or less. The technical details of angioplasty and atherectomy have been reviewed elsewhere.[10,11] Crossover to the other treatment method was strongly discouraged, although it was recognized at the outset of the trial that in approximately 30 percent of patients the rigid atherectomy device would require pretreatment with balloon dilation before the atherectomy catheter could be advanced.[7] At the beginning and end of each procedure, a coronary angiogram of the target vessel was obtained in two orthogonal views with either a 7-French or an 8-French catheter after the administration of 200 μg of intracoronary nitroglycerin to standardize the quantitative coronary angiography. The same procedure was used at the follow-up coronary angiography performed at six months, to match the original views.

Before the procedure, aspirin was given in a dose of 325 mg per day or more for at least one day, and at least one dose of a calcium-channel blocker was administered. Heparin was administered as a bolus of 10,000 U, with additional boluses to maintain the activated clotting time above 300 seconds during the procedure. At the discretion of the investigator, the femoral access sheaths were removed 4 to 24 hours after the procedure, with attention paid to the adoption of a uniform protocol at each site regardless of the treatment assignment. Before and within 24 hours after the procedure, a 12-lead electrocardiogram was obtained, and creatine kinase levels with myocardial isoenzymes were measured serially every 8 hours after the procedure for a total of three samples. After the procedure, aspirin (325 mg per day) and a calcium-channel blocker were prescribed for one month. No other cardiovascular medications were recommended unless they were specifically prescribed by the investigators to treat other preexisting medical conditions.

Angiographic Laboratory

The cineangiograms were forwarded to the laboratory of the Cleveland Clinic Foundation for independent, blinded assessment of the initial and follow-up quantitative coronary angiograms. These assessments were made from the paired initial and follow-up angiograms, with the technicians unaware of the treatment assignments and with any images that showed the procedural devices spliced out. Although multiple views of each lesion were quantified, only the most severe hemisegial view of the stenosis without foreshortening was selected for analysis. End-diastolic cine frames from orthogonal views were digitized with a cine-video converter and a computer-assisted edge-detection algorithm.[9]

Pathology Laboratory

Tissue specimens retrieved from the atherectomy catheter were immediately placed in 4 percent paraformaldehyde for 30 minutes, after which they were stored at 4°C in 30 percent sucrose–phosphate-buffered saline and forwarded to the laboratory at St. Elizabeth's Hospital in Boston. A portion of the specimen was postfixed in 10 percent formalin and analyzed by light microscopy and immunohistochemical analysis.

Economics and Quality-of-Life Assessment

At 19 of the 32 U.S. study sites, the investigators and research nurses volunteered to participate in a substudy examining hospital costs, other economic outcomes, and quality of life. All hospital bills covering the period from enrollment to the six-month follow-up assessment were collected prospectively. In addition, each patient had quality-of-life assessments at base line and at six months. Data on hospital charges were converted to hospital costs with site-or center-specific Medicare cost-to-charge ratios and per diems from each hospital's Medicare Cost Report.[12]

End Points

The primary end point in the trial was angiographic restenosis, defined as stenosis of more than 50 percent six months after an initially successful procedure. The other angiographic indexes assessed included the success rate, with success defined as a reduction in stenosis to 50 percent or less as assessed by quantitative angiography, the actual percentage of stenosis before and after the procedure and at six months of follow-up, the absolute minimal luminal diameter of the target lesion, and the caliber of the target vessel. All these angiographic end points, including early success and restenosis, were assessed at the angiographic laboratory.

A composite early clinical end point, indicative of the safety of the procedures, was prospectively defined to include death, emergency coronary artery bypass surgery, acute myocardial infarction, and abrupt vessel closure during the period of hospitalization after randomization. A composite six-month clinical end point was also prospectively defined as described below. Myocardial infarction was diagnosed both clinically at the participating site and by an adjudication committee unaware of the treatment assignment, on

the basis of the development of new Q waves or the elevation of creatine kinase myocardial-band isoenzymes to more than three times the upper limit of normal for the site.

Data Management and Statistical Analysis

All the data were prospectively recorded by the research coordinator and investigators at each site in case-report forms, forwarded to the coordinating center at Duke University, and verified by range and consistency checks and double data entry, with queries sent back to the sites about any missing or inconsistent data. To ensure the quality of the data, cardiology nurses at the coordinating center audited all case-report forms and documented a random 15 percent of the forms, using the source medical records at the site.

Continuous data were expressed as medians, with 25th and 75th percentiles unless otherwise indicated. Selected base-line characteristics and key clinical and angiographic outcomes were compared between treatment groups by the chi-square test or Fisher's exact test in the case of discrete variables and by the Wilcoxon rank-sum test in the case of continuous variables. The occurrence of clinical outcomes during the six-month follow-up period was characterized with Kaplan–Meier survival curves, and the treatments were compared by the log-rank statistic.[9] The treatments were compared with regard to the six-month composite end point with use of ordinal logistic regression.[8] All tests of significance were two-tailed, and the treatments were compared by the intention-to-treat principle. Multiple linear regression analysis was used to assess the relative strength of the relation of the treatment and selected other clinical factors with the luminal diameter at six months. The clinical factors considered were minimal luminal diameter after the procedure, age, sex, the presence of diabetes, unstable as compared with stable angina, location of the lesion in the left anterior descending artery, vessel caliber, and the occurrence of acute periprocedural complications. For a prespecified subgroup that included patients with lesions in the proximal left anterior descending artery, an assessment of whether the effect of atherectomy on restenosis differed from its effect in other patients was made by logistic regression and testing for an interaction between treatment and subgroup.

Relationship with Sponsors

The steering committee, consisting of the principal investigators at each site, set firm standards for the design and execution of the protocol, which was conducted in a manner completely independent of the sponsors (Devices for Vascular Intervention, Redwood City, Calif., and Eli Lilly, Indianapolis). The steering committee, as well as the members of the Data and Safety-Monitoring Committee and the coordinating center, were not permitted to have a financial interest in the sponsors or to serve as consultants or part-time employees of the sponsors. This requirement also applied to the investigators' spouses and family members. All the data generated in the trial were handled at the coordinating center. The study data were not made accessible to the investigators or sponsors until the six-month follow-up data were complete and the analysis had been performed.

Results

Characteristics of the Patients

Enrollment in the study began August 15, 1991, and ended April 30, 1992, by which time 1012 patients had been entered. The relevant base-line characteristics of the patients enrolled are shown in Table 1. The two groups were well balanced with respect to all cardiovascular risk factors. The population consisted predominantly of patients with unstable angina. This clinical diagnosis was supported by a diagnosis in the angiographic laboratory of thrombus in the lesion in nearly 20 percent of the patients in both groups; thrombus was identified histologically in 36 percent of the lesions treated by atherectomy.

Table 1. Base-Line Clinical and Angiographic Characteristics.*

Characteristic	Atherectomy (N = 532)		Angioplasty (N = 535)	
Age (yr)	59	(51, 67)	58	(51, 67)
Male sex (%)	75		73	
Weight (kg)	82	(73, 93)	82	(72, 93)
Height (cm)	172	(165, 178)	173	(165, 178)
Diabetes (%)	19		19	
Current smoker (%)	28		28	
Hypertension (%)	52		54	
Hypercholesterolemia (%)	45		43	
Cholesterol (mg/dl)†	217	(190, 250)	218	(188, 247)
History of MI (%)	44		41	
Unstable angina (%)‡	66		70	
Pain at rest	46		44	
Pain with ECG changes	21		18	
Angina after MI	18		18	
Accelerating pattern	63		61	
Target vessel (%)				
Left main	0.6		0.6	
Left anterior descending	58		56	
Left circumflex	14		10	
Right coronary artery	28		34	
Ejection fraction	59	(50, 65)	58	(50, 65)
No. of diseased vessels — % of group				
1	66		65	
2	26		29	
3	5		6	
Thrombus (%)§	20		18	
Lesion length (mm)§	8.9 (6.6, 11.8)		8.6 (6.3, 12.0)	
Vessel caliber (mm)§	3.9 (2.5, 3.3)		3.9 (2.5, 3.3)	
% Stenosis§	71	(65, 78)	72	(64, 79)

*Percentages shown are percentages of the study group. Numbers followed by parentheses are medians; the first number inside the parentheses is the 25th percentile, and the second number the 75th percentile. MI denotes myocardial infarction, and ECG electrocardiographic.

†To convert values to millimoles per liter, multiply by 0.02586.

‡Patients with unstable angina can be included in more than one subcategory.

§As determined by the angiographic laboratory; the median vessel calibers determined by the site investigators were 3.2 mm in the atherectomy group and 3.3 mm in the angioplasty group.

A sampling of the complete profile of interventional procedures in the "universe" sample indicated that 13 percent of the procedures at the participating centers were performed with directional atherectomy and that the patients who underwent them had larger target vessels with more proximal and eccentric lesions. Among the 1734 patients who underwent atherectomy at the study sites during the course of the trial, 470 patients (27 percent) were eligible for enrollment but underwent atherectomy on a nonrandomized basis because of the investigator's preference for the procedure; this selection bias occurred primarily at three sites where there was low enrollment.

Procedural and In-Hospital Outcomes

The principal results of the procedures are shown in Table 2. The rate of crossover from atherectomy to conventional balloon angioplasty was 17 percent; for crossover from angioplasty to atherectomy, it was 4 percent. Methods of revascularization other than that assigned, including perfusion balloons, stents, or

other atherectomy or laser devices, were used in 26 percent of the patients undergoing atherectomy as compared with 14 percent of those undergoing angioplasty. As evaluated by site investigators, the success rate (the rate at which a reduction in stenosis to 50 percent or less was achieved) was 96.4 percent in both groups, but angiographic review found a higher success rate for atherectomy than for angioplasty (89 percent vs. 86 percent, P<0.001). The success rates as defined on the basis of quantitative angiographic stenosis of 50 percent or less and no major complications (such as death, infarction, or emergency bypass surgery) were 82 percent and 76 percent, respectively (P = 0.016). Atherectomy led to a greater immediate gain in the diameter of the vessel than angioplasty (1.03 vs. 0.86 mm, P<0.001).

The in-hospital clinical outcomes are shown in Table 2. There was a higher rate of myocardial infarction among the patients undergoing atherectomy than among those undergoing angioplasty (6 percent vs. 3 percent, P = 0.035) and a higher rate of early composite events in the atherectomy group as compared with the angioplasty group (37 events [11 percent] vs. 27 events [5 percent], P<0.001). On blinded assessment of the serial creatine kinase enzyme measurements and electrocardiographic data, the overall frequency of myocardial infarction, including both clinical and laboratory diagnoses, was 19 percent for atherectomy as compared with 8 percent for angioplasty (P<0.001). Since the importance of myocardial infarction detected on the basis of abnormal enzyme levels alone, without clinical or electrocardiographic signs, is unknown in this setting, the data on enzyme-based diagnoses are reported in Table 2, but in the presentation of clinical end points only the clinical diagnosis is used.

Hospital costs are shown in Table 3 for 605 patients enrolled at the 19 sites participating in the substudy. With respect to base-line characteristics and results of the procedure, these patients were representative of the entire study population.

Table 2. Technical Features and Results of the Procedures.*

Variable	Atherectomy (N = 512)	Angioplasty (N = 509)
Procedural features		
Maximal size of equipment (%)		
Atherectomy catheter		
5 French	1	—
6 French	32	—
7 French	67	—
Balloon catheter (mm)		
<3.0	—	6
3.0–4.0	—	83
>4.0	—	11
Use of opposite technique (%)†	18	8
Use of perfusion balloon (%)	11	11
Stent or laser use (%)	1.2	0.4
Use of any other device (%)	36	14
Final % stenosis		
Assessed visually by site	15	26
Assessed quantitatively by angiographic laboratory	29	36
Final minimal luminal diameter (mm)	2.02	1.89
Perforation (%)	0.4	0.2
In-hospital outcomes (%)		
Death	0	0.4
Myocardial infarction		
Detected clinically by site	5	3
Q wave	2	2
Non-Q wave	4	1
Detected by adjudicators, abnormal enzymes only	10	5
Emergency CABG	3	2
Abrupt vessel closure	2	1
Early phase composite end point‡	11	5

*Percentages shown are percentages of patients in the study group. CABG denotes coronary artery bypass surgery.

†Includes lesion predilation, performed in 10 percent of the patients undergoing atherectomy in order to gain access to the target lesion.

‡Includes death, emergency CABG, acute myocardial infarction, and abrupt vessel closure during hospitalization after randomization.

Restenosis and Clinical Outcomes at Six Months

Of the 850 eligible patients, 862 (90 percent) had angiographic follow-up. Follow-up angiography was not performed in the remaining patients for the following reasons: unwillingness to undergo the procedure (73 patients), death (9 patients), intercurrent illness (5 patients), and loss to follow-up (10 patients). The rate of restenosis according to the definition of the primary end point was 50 percent in the atherectomy group as compared with 57 percent in the angioplasty group in the 825 patients who could be evaluated and for whom there were technically adequate paired data (P = 0.06). Figure 1 shows plots of the distribution of minimal luminal diameter that incorporate all the patients in the trial who were included in the paired analysis, whether or not they had angiographic success initially. A regression analysis of the determinants of six-month minimal luminal diameter, with control for treatment assignment, revealed that the final minimal luminal diameter after the procedure was the single most important determinant of subsequent lumen caliber (F = 84.7, P<0.001). The only other important determinants were the vessel size before the intervention (F = 15.6, P<0.001), the presence of diabetes mellitus (F = 10.5, P = 0.001), and location of the lesion in the proximal left anterior descending artery (F = 5.4, P = 0.02).

The subgroup of patients with stenosis in the proximal left anterior descending artery who were identified at the outset of the trial appeared to have a lower rate of restenosis with atherectomy; among these patients, the rate was 51 percent in the atherectomy group as compared with 63 percent in the angioplasty group (P = 0.04). The restenosis rate for other lesions was 49 percent in the atherectomy group as compared with 50 percent in the angioplasty group. The minimal luminal diameter of the proximal left anterior descending artery at six months was 1.32 mm in the

Table 3. Mean Hospital Costs and Length of Stay for 805 Representative Study Patients.

Variable	Atherectomy (N = 396)	Angioplasty (N = 409)	P Value
	dollars		
Total cost per patient	11,503	10,637	0.002
Room	956	926	
Coronary care unit	2,494	2,284	
Cardiac catheterization lab	4,397	3,624	
Laboratory	572	529	
Pharmacy	691	556	
Radiography/procedure	299	308	
Operating room/anesthesia	576	531	
Blood bank	35	32	
Medical supplies	1,506	1,302	
Other	453	388	
Total charges	17,499	15,283	0.004
	days		
Length of stay	5.7	5.5	

atherectomy group as compared with 1.12 mm in the angioplasty group ($P = 0.038$); for lesions in the other target vessels, the final diameters were 1.42 and 1.44 mm, respectively. The interaction between treatment and subgroup was statistically significant ($P = 0.03$). The angiographic benefit in the subgroup of patients with lesions in the proximal left anterior descending coronary artery was not associated with any distinct advantages in clinical outcomes or reduced periprocedural complications.

The cumulative six-month clinical outcomes are shown in Table 4, and the actuarial analysis in Figure 2. All eight deaths in the atherectomy group occurred after the initial hospitalization. Three were related to peripheral vascular complications of the procedure, and five were from cardiovascular causes. The increased rate of myocardial infarction in the atherectomy group was statistically significant. Exercise testing, performed in 71 percent of the patients during follow-up, revealed no significant differences between the two groups. The median treadmill exercise time was 8.2 minutes in both groups. The patients in the atherectomy group and those in the angioplasty group had similar rates of positive exercise tests (36 percent vs. 32 percent, respectively) and ST-segment depression with exercise (32 percent vs. 38 percent, respectively).

Discussion

This randomized trial comparing coronary atherectomy with angioplasty demonstrated a small reduction with atherectomy in the primary end point, angiographic restenosis at six months, at the expense of a higher rate of periprocedural complications. The latter finding was unanticipated and accounts in large part for the worse clinical outcomes at six months with atherectomy. Besides the concern about the safety of the newer procedure as compared with angioplasty, this trial provides insight into the importance of achieving a wide lumen to avoid angiographic restenosis.

Restenosis is the most important and vexing problem complicating balloon angioplasty. It occurs in a substantial minority of patients within a period of six months after the procedure and accounts for approximately $2 billion per year in health care expenditures in the United States for repeat angioplasty and bypass surgery.[5] There have been several large-scale, well-conducted trials testing pharmacologic strategies such as the use of angiotensin-converting-enzyme inhibitors, heparin fragments, steroids, and thromboxane antagonists,[10-14] none of which have reduced the rate of restenosis. The current trial shows that the rate of restenosis can be improved with atherectomy, but the overall rate was still quite high and the improvement relatively small.

The high rates of restenosis in both study groups can be attributed in part to the high prevalence of unstable angina, which is known to be an important base-line risk factor for restenosis after coronary angioplasty.[15,16] By quantitative coronary angiography it has been shown that luminal renarrowing follows a nearly Gaussian distribution after coronary angioplasty, atherectomy, and stenting,[17,18] and the time course is similar for the various revascularization techniques.[16,17] Although the observed rate of 50 percent for restenosis seems high, it approximates the rate reported by Nobuyoshi and colleagues in the landmark serial study of angiographic restenosis after angioplasty.[19] It is important to keep in mind the critical difference in rates between angiographic and clinical restenosis, since the latter is best estimated by the rate at which subsequent coronary revascularization is needed, which was approximately 35 percent in both groups in this study.

Our data reinforce the fundamental finding of Bain, Kuntz, and colleagues[20,21] that "bigger is better" in the sense that greater early luminal enlarge-

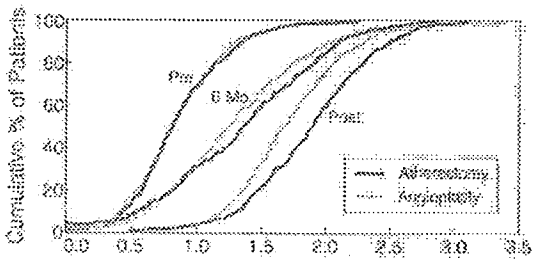

Figure 1. Cumulative Frequency Distribution of the Minimal Luminal Diameter of the Target Lesion in the Two Study Groups. There was no difference in the base-line distribution (Pre), but at the end of the procedure (Post), more improvement was seen with atherectomy ($P < 0.01$). At the six-month follow-up (6 Mo) the difference narrowed, but a trend favoring atherectomy remained ($P = 0.06$).